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Wireless Tactical Networks in Support of Undersea Research

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Introduction

Emerging concepts for Anti-Submarine Warfare (ASW) and Rapid Environmental Assessment (REA) increasingly rely on communication technology, in order to implement distributed information networks and to exchange information between naval units and military commands ashore. The necessary communication links could be accomplished using a variety of solutions: our main focus is on radio frequency (RF) links, which offer easy deployment and flexible operations.

Requirements (such as transmission data rate) change from one specific application to another. There are however a number of prerequisites that are shared by all applications and users: they include, but are not limited to, reliability, availability and security.

The biggest challenge derives from the fact that those requirements are countered by either natural factors, such as thermal noise and multipath interference, or by hostile activity aimed at disrupting the integrity of the lines of communication.

This document illustrates how spread-spectrum techniques can be adopted to substitute and enhance existing communications systems, to permit the deployment of distributed, scalable networks of ships and sensors, characterized by reliable performance (resistance to hostile jamming and environmental interference) and low probability of interception. An overview of real applications in ASW and REA is presented.

Wireless communications at sea

Sophisticated sensors and information technology require the transfer of large flows of data. Current communication systems are limited in their throughput capability not only by technical limits, but above all by regulations about frequency assignment and by interference inherent to the frequency bands in use. For example, frequencies ranging from 2 MHz to 2 GHz, where the majority of naval communication systems are located, are crowded with signals generated by commercial users and radar emissions. In addition to that, the bandwidth that is made available to a single user is limited by practical reasons and by international regulations.

Frequencies above 2 GHz are less densely populated, and wider RF bandwidths are available. Operating at those high frequencies solves the problem of bandwidth availability and limits the adverse effects of thermal noise: it is a well known fact that the sky noise temperature is minimum at frequencies between 1 and 10 GHz, in the so-called *microwave window* [Skla-88], as shown in figure 1. Moreover, stronger atmospheric absorption reduces interference from other users of the same channels. On the other hand, a large number of issues are still to be considered: for example, resistance to multipath interference and hostile jamming. Efficient use of radio communication resources is also important, to allow scalable and efficient operations with dynamic deployment topologies for ships and sensor platforms.

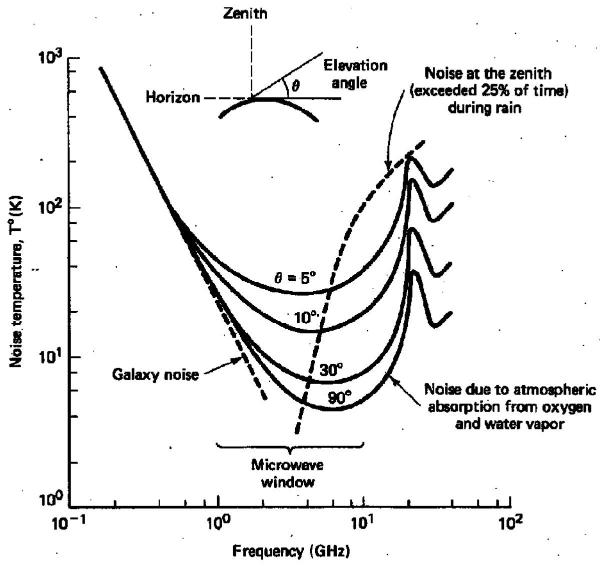

Figure 1 – Sky Noise temperature versus frequency (from [Skla-88])

Line of sight communications take place with low grazing angles; they correspond to the flattest curve of the above plot ($\theta = 5$ degrees). The most interesting frequency band appears to be in the 2 GHz – 10 GHz range. Further system parameters (e.g. antenna size, data rate, range to be achieved) need to be considered in the final choice of the operating frequencies.

Benefits of Spread-Spectrum communications

In the study of digital communications systems, spectral and power efficiency represent important qualifying factors: in general terms, it is necessary to exploit effectively available radio frequency bandwidth and transmission power. In addition to that, technical shortcomings could be present, such as operation from a platform where available electrical power is limited (e.g. a battery-powered buoy).

Paper presented at the RTO IST Symposium on "New Information Processing Techniques for Military Systems", held in Istanbul, Turkey, 9-11 October 2000, and published in RTO MP-049.

Spectral efficiency is practically defined as:

$$n_s = \frac{R}{B_W} = \frac{transmission\_rate}{required\_bandwidth}$$

where

n_s = Spectral efficiency or bandwidth efficiency defined in b/s/Hz

R = Transmission rate in b/s

B_W = Bandwidth

Traditional modulation schemes aim at *maximizing* spectral efficiency. However, interesting advantages can be obtained using a very large radio frequency bandwidth. Such a transmission technique is called *spread-spectrum* (SS) and has been developed since the mid-1950's in support of military applications, including secure tactical communications. In SS systems, the bandwidth spread is achieved using a code that is independent of the data: subsequent despreading and data recovery at the receiver is performed with the same code, in association with synchronization techniques. Spreading the spectrum in the appropriate way leads to multiple simultaneous benefits. Some of these are:

- Improved interference rejection
- Antijam capability
- Code division multiplexing for multiple access applications
- Low-density power spectra for covert transmission
- High-resolution ranging and timing
- Secure communications

The techniques by which the signal spreading can be accomplished are various: the most common and interesting techniques are termed *direct-sequence* and *frequency hopping*. In *direct-sequence spread-spectrum* (DSSS) a fast pseudo-random sequence, termed *pseudo-noise* (PN) *sequence*, is applied to the signal that needs to be transmitted, causing phase transitions in the data carrier. In *frequency-hopping spread-spectrum* (FHSS) the PN sequence forces the carrier to rapidly drift its frequency in a pseudo-random way. The use of a larger portion of RF bandwidth is compensated for by the interference advantages anticipated above. Signal energy becomes so diluted that the amount of power density present in any point within the spread signal is very limited. The dilution may result in the signal falling below the noise floor, and thus becoming invisible to receivers that are not sharing an appropriate despreading code.

DoD and Commercial-off-the-shelf implementations

The U.S. Department of Defense is in the process of specifying and developing a new wireless networking radio capable of transmitting voice, video, and data between its mobile vehicles, aircrafts, and ships. Among the most promising systems that are being evaluated are the Department of Defense Near Term Digital Radio (NTDR), GEC Marconi Hazeltine VRC-99, as well as Commercial-Off-The-Shelf CSMA/CA systems, such as those defined by standard IEEE 802.11. Specific research projects are being conducted at the Naval Research Laboratory and at SPAWAR Systems Center, San Diego [8].

The NTDR is a tactical radio developed by ITT for mobile networked Internet protocol data applications. The NTDR handles data packet information at a burst rate of 375 kbps. d. The resulting coded signal is modulated onto a Direct Sequence Spread Spectrum (DSSS) waveform at 500 kbps and transmitted at up to 20 Watts (+43 dBm) in the 225-450 MHz band. For a simple point-to-point connection the maximum throughput is about 250 kbps.

The VRC-99 is a direct sequence spread spectrum radio manufactured by GEC-Marconi Hazeltine guaranteeing reliable, simultaneous, multichannel voice, data, imagery, and video transmission. Data rate is 625 kbps with options of adaptive data rate operation from 157 kbps to 10 Mbps. Low probability of intercept and jamming resistance is achieved through specialized direct-sequence and frequency-hopping spread-spectrum techniques. Operation is conducted in the 1.2-2 GHz frequency band. The VRC-99 supports IP data from a standard Ethernet local area network (LAN) and up to four simultaneous voice telephone links.

In addition to the above systems, which are specifically conceived for military use, Commercial-Off-The-Shelf systems are being studied to assess their effectiveness. COTS systems are usually based on open standards, which implies availability of products from multiple suppliers on a shorter time scale, at a lower cost. It is possible either to purchase a complete turnkey system or to build up a custom made one to match specific requirement, using available chipsets and RF components.

COTS equipment is typically configured to operate in the ISM (Industrial, Scientific and Medical) frequency band (2.4 GHz and 5.7 GHz). License-free operation is granted for transmission in the ISM band using spread-spectrum equipment, provided limits on transmit power are respected (typically 0.1 W). Operation at higher transmit power is usually subject to approval by the national authorities.

“802.11” is the first true industry standard for Wireless Local Area Networks, or "WLANs". Developed by the Institute of Electrical and Electronics Engineers (IEEE), 802.11 can be compared to the 802.3 standard for Ethernet wired LANs. The goal of 802.11 is to provide a standard set of operational rules so that WLAN products from different manufacturers interoperate in the same way that Ethernet equipment does today.

The physical layer of IEEE 802.11 includes three alternatives: DFIR (Diffuse Infra-Red), DSSS, and FHSS. Both the DS and FH spread spectrum specifications utilize the 2.4 GHz radio frequency band. The 2.4 GHz band was chosen because it is available for unlicensed operation worldwide and because it is possible to build low cost, low power radios in this frequency range that operate at LAN speeds.

The shared access of several users to a single frequency band is implemented by ad-hoc protocols.

IEEE 802.11 and other relevant WLAN products, such as P-Com Datametro II, use the CSMA/CA (Carrier Sense Multiple Access/Collision *Avoidance*) access method, which is, in turn, derived from the Ethernet standard, CSMA/CD (Carrier Sense Multiple Access/Collision *Detection*). In a nutshell, CSMA/CA applies a "listen before talk" approach that can minimize collisions by using request to send (RTS), clear-to-send (CTS), data and acknowledge (ACK) transmission frames, in a sequential fashion. This results in higher system throughput and better frequency utilization.

Applications

Naval operations and field experiments both require underlying communication architectures capable of delivering the required services. The following table lists some key services that are of interest to naval users, together with the associated data rates.

Service	*Data rate (kbps)*
Automated real-time decision aides	>64
Concurrent, distributed data bases	>64
Data fusion	>64
Data transfer (vertical arrays, sonobuoys, DUSS)	Up to 10 Mbps
Distributed computing	Up to 10 Mbps
Distributed white board	>64
High-resolution imagery	>64
High-resolution maps	>64
Voice	>2.4
Web browsing	>64

Important requirements relative to availability, reliability and security are summarised in the following list:

1. Guarantee of data integrity
2. Protection from denial of service
3. Low battery power requirements
4. Low probability of intercept
5. Source authentication

Spread-spectrum with no doubt fulfils requirements 2, 3 and 4.

Low battery power requirements and low probability of intercept are strongly correlated: spread-spectrum transmission is stealth by its own nature. In addition to that, effective data transmission is accomplished with limited transmission power. Hostile interference is not fought by brute force (increasing the transmission power), but by more advanced techniques. The result is that spread spectrum equipment can be easily operated from a battery: Commercial-Off-The-Shelf spread-spectrum radios are capable of delivering data rates in the order of several Megabits per second up to the distance of 20 n.mi., with transmission power lower than 1 W.

Requirements 5 and 6 cannot be satisfied totally by simply adopting spread-spectrum techniques: better results would probably be obtained operating at the application level, using appropriate authentication schemes which should be supplemented by strong encryption. Nevertheless, since a spread-spectrum wireless network node can communicate with the other nodes only by using the appropriate PN code, it can be said that SS plays a non marginal role in satisfying source authentication requirements.

Rapid Environmental Assessment

To accomplish their mission, naval forces rely on all kinds of environmental data. Weather and climatology information, tide atlases, satellite images of cloud cover, and oceanographic databases are regularly generated and distributed: this activity of preparation, collection and delivery of standard environmental products represents the standard level of service offered to navy customers. A situation may however arise, when oceanographic support centres are not able to supply the environmental information that is needed by naval commanders and planners. In such a case, a request is issued to the NATO military oceanography (MILOC) group, to conduct specific surveys in the area of interest to acquire the necessary data.

In the past, the whole process of data collection, processing and distribution of a final environmental report always took several years. Such a long delivery time was not deemed satisfactory by the end users, which formulated a requirement to obtain operationally relevant products within a tactically relevant time frame after the identification of a particular area. The definition of "tactically relevant time frame" ranges from several months, during the operational planning phase, to few days, during navy operations.

Acceleration of traditional methodologies (e.g. re-assignment of priorities in data collection processing) can reduce the delivery times from several years to few months, which is not even close to meeting the most stringent requirements.

Rapid Environmental Assessment (REA) is a set of state of the art methodologies and techniques that enable the collection, processing and distribution of environmental data and products within a compressed time frame, in the order of days, if not hours.

The REA concept requires the collection of in-situ data by one or more survey vessels, as illustrated in figure 2. Survey vessels perform the necessary environmental measurements and relay the information to a data fusion centre afloat (e.g. a command ship), which can be positioned several miles away. Fused data are then transferred to a fusion centre ashore, where they are made available to the REA community (data providers, product developers, and customers) using wide-area computer networks. [Sell-99], [TFB-99].

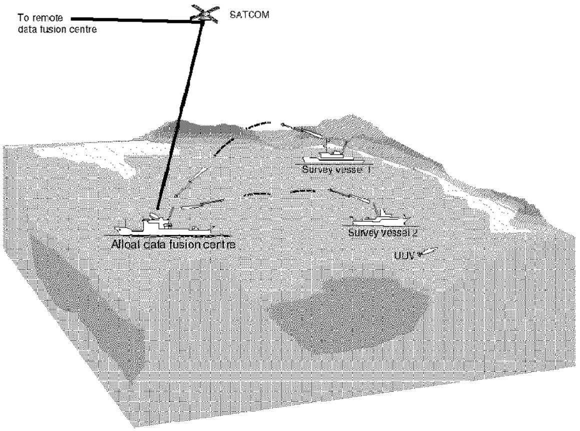

Figure 2 - Transmission of REA information from survey vessels to a data fusion centre

REA experiments conducted so far constitute proof of the effectiveness of the REA concept: however, additional efforts are still necessary to define a communication architecture suitable for use in operational conditions. There is no doubt that the availability of reliable and scalable ship-to-ship data links is of paramount importance to the effectiveness of REA surveys.

During a crisis the access to commercial land-based communication infrastructures (such as cellular phone networks) will be easily denied. It is very important that the communication architecture that is defined is independent from local infrastructures. On the basis of the above consideration, the deployment of a wireless LAN connecting the survey vessels is a practical solution.

The WLAN, implemented using medium or high data rate RF links with a high resistance to multipath interference and hostile jamming, is the first level of the REA tactical network. The second level is the long-range communication link, typically implemented using SATCOM, which connects the survey group to the commands ashore.

Spread-spectrum makes an excellent candidate to implement the REA tactical network. When operating near the shore, a major challenge comes from the multipath interference that is caused by reflections of RF waves by the sea surface and by the land. The characteristics of robustness to multipath interference of spread-spectrum enable the delivery of reliable wireless data communication at the required high data rate. The LPI and LPD properties of spread-spectrum, together with resistance to hostile jamming, may prove extremely useful for adoption in an operational situation.

Computer simulations using the AREPS model [Patt-98] show that ship-to-ship communications can achieve a maximum range of 18 n.mi. (21 n.mi. when directive antennae are used) with only 1 W of transmit power, operating in the 2 GHz frequency range with antenna masts 33 m high, as summarized in the following table.

Transmit power	Antenna type	Range (n.mi.)
1 W	Omnidirectional	18
1 W	Directive (*)	21

(*) requires tracking system to ensure antenna alignment

Tests have been conducted during SACLANTCEN experiment **Advent 99** in May 1999, to demonstrate the effectiveness of the concept. Italian Navy ship Ciclope towed a CTD chain and transferred data in quasi-real time to NRV Alliance, using a DSSS link with a data rate of 128 kbps and a transmit power of 0.6 W. NRV Alliance was positioned at a maximum distance of 10 n.mi.

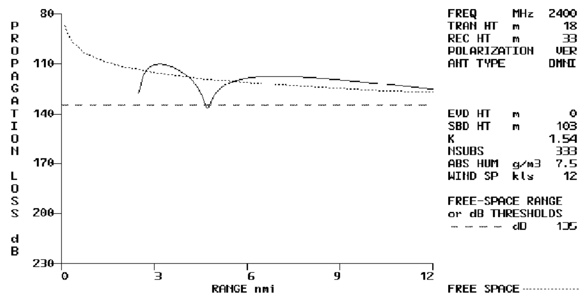

Figure 3 - Propagation loss (red) for the Advent 99 DSSS radio link. The blue dashed line represents the communication threshold

The spread-spectrum communication system was judged extremely reliable and contributed to the success of the experiment.

A brief interruption of the link has been observed, as a consequence of the multipath effects due to reflections from sea surface. This is in accordance with RF propagation loss predictions computed using the EREPS model and the methodologies described in [MBG-99]. The result is summarized in figure 3: multipath induced propagation loss brings the system below communication threshold at the range of 4.7 n.mi. Loss of signal is observed for an additional 0.1 n.mi, where communications is resumed. From the range of 4.8 n.mi onwards, communication is stable and reliable, up to a range exceeding 12 n.mi.

The first operational application of the concept took place during ACLANT exercise Linked Seas 2000, in May 2000. A REA precursor phase has been conducted, in support of amphibious operations: HMS Roebuck, SPS Don Carlos and FS La Perouse were linked by a WLAN implemented using P-Com Datametro units, as illustrated in fig. 2.

All data collected in the course of the exercise (in the order of 30 MB) were distributed among the participating vessels and transferred to the SACLANTCEN data fusion centre using SATCOM.

Deployable Underwater Surveillance Systems

ASW nowadays places very demanding requirements on sonar capabilities, in an era of shrinking budgets. Protection of worldwide commercial flows on sea routes from the attacks or mining operations of hostile submarines have become the highest priority. The areas of interest have now moved to shallow littoral waters and choke points, characterized by heavy (and noisy) shipping traffic, poor and complex sound propagation, strong reverberation. The submarines that need to be countered are now small, diesel electric vessels, already too silent for easy passive detection, and now undergoing major technological improvements like sound absorbing cladding, air independent propulsion, modern passive sonars (towed and flank arrays) and navigation systems. Finally, operational requirements have become very strict in terms of probability of detection, completeness and accuracy of coverage, risk for naval units and personnel, discretion, interoperability.

SACLANTCEN is conducting theoretical and experimental investigations on Deployed Undersea Surveillance systems to meet these requirements. The new concept consists of multiple acoustic sources and receivers: small, inexpensive, expendable elements easily deployed from any air or sea platform (Figure 4).

Sonar units can be drifting, moored to the bottom at chosen depths or laid directly on the seabed. Battery powered, they are autonomous and transmit data in compressed form via radio, satellite link, optic fiber or other. The moderate gain receivers, which may be used also in passive mode, have the advantage of no own ship noise and can be laid to form a large network extended over wide areas. The covertness of receivers suits operations in critical areas and improves chances of detection of unaware submarines (that optimize their course only with respect to the transmitter position) with either a favorable aspect angle or Doppler shift.

Figure 5 illustrates the advantages of aspect diversity.

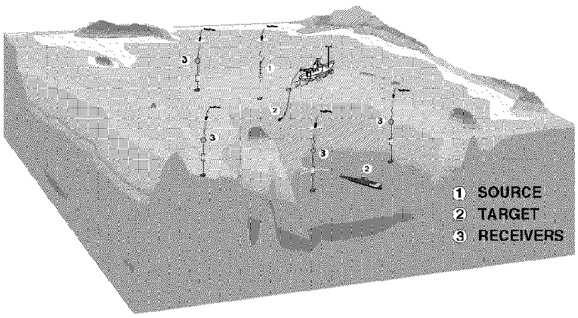

Figure 4 - Pictorial view of the DUSS concept.

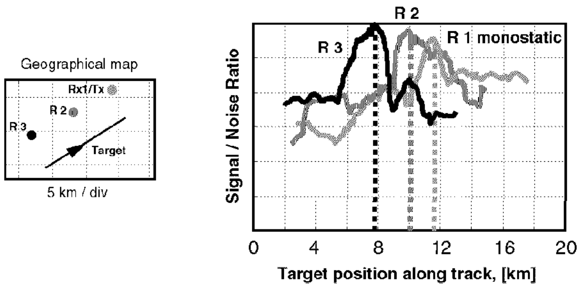

Figure 5 - Target detection opportunities are multiplied by the deployment of additional multistatic receivers.

Elementary detection volumes can be overlapped: each node has an independent opportunity to detect the target, while inter-sensor data fusion reduces false alarms and exploits deployment geometry to enhance localization and tracking.

A field of moored elements facilitates detection of any moving object, as the background remains relatively stationary. Towed sources, on the other hand, are not subject to the same critical constraints in power and endurance, while the towing ship does not need to be the master operation center.

Figure 6 shows raw sonar displays for three separate receivers.

The feasibility of the whole concept largely relies on the recent advances of communication, geographical localization and digital processing techniques, which permit distributed sonar processing on small autonomous nodes and transmission of the data collected in compressed form. Different degrees of data reduction before transmission are possible, according to the tasks to be executed. The following sections address the two cases of scientific experiments and of demonstrators approaching operational conditions.

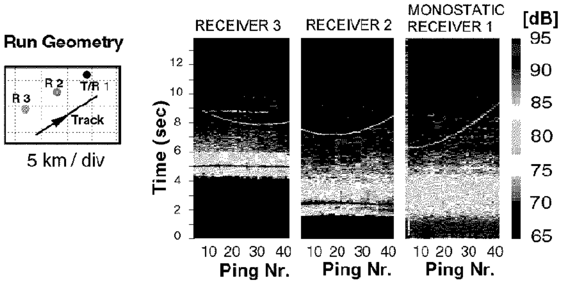

Figure 6 - Raw data on sonar displays for three DUSS receivers.

DUSS radio link specifications

Accurate collection of scientific data requires hydrophone data to be stored with a large dynamic range. The whole bunch of information collected by the sensors is transmitted to the laboratory on NRV Alliance and maintained for successive off-line processing and analyses that can not be anticipated during the experiments. Data reduction is limited, in this case, to base-band filtering and shifting. The follow on estimates requirements for DUSS.

Raw data: recordings of raw data on board Alliance are mandatory for scientific work. Therefore they will always be required as a first – priority output for all experiments. In-buoy recordings are also being considered, and represent a safe backup resource. Expected rates are 24 bits * 64 Hydr. * 1365 Hz = **2 Mbps**

Compressed data: an operational DUSS may resorts to in-buoy processing and implement a distributed - knowledge, distributed-processing network. Pre-processed contact information is passed through the net in a packet switching fashion. Data rates are reduced. This section tries to produce an estimate of expected reduction ratios by considering very simple approaches.

- Geographical map of cells: range resolution reduced to 50 m via pre-processing. Max range: 30 km. 600 cells. 8 bits per cell (e.g. level coded in dB of SNR after normalization and thresholding between 0 and 32 dB in 0.5 dB steps). 64 beams. Total: **5 kbps**.
- Markov Random Field processing: this method transforms the raw sonar display into a list of OBJECTS. Each of them is described by time, bearing, size, level (i.e. 16 bytes). Analyses of experimental data (DUSS and SWAC data) estimated an average reduction between 1% and 0.1% of the number of raw sonar cells to objects. Assuming 2 bytes/cell and 16 bytes/object, 1% data rate reductions represent a reasonable conservative guess for reverberating environments after full development of this method. Total: **20 kbps**.
- Thresholding: The experimental probability of false alarm is plotted versus level in dB with respect to normalized background. Contacts above 6 dB represent 1 % of the total. Their range needs to be stored in sparse files. Their level can be recorded with just 1 byte. The result is a 1 % compression ratio. Total **20 kbps**.

Estimated rates sum up together when a Local Area Network (LAN) structure is used, with nodes that forward data through the network together further to broadcasting their own contacts.

- Bit error rate (BER) requirements for raw data acquisition range from 10^{-3} to 10^{-5}. In fact, as shown by field experiments, the isolated error bursts that occur on radio data links can easily be detected, and do not affect the measurements.
- On the contrary, compressed data require lower BER, around 10^{-8}, thus partially losing the advantage of a lower data rate.
- Typical working ranges, necessary for significant multistatic sonar tests, are of 10 n.mi.

Accurate collection of scientific data requires hydrophone data to be stored with a large dynamic range. The whole bunch of information collected by the sensors is transmitted to the laboratory on NRV Alliance and maintained for successive off-line processing and analyses that can not be anticipated during the experiments. Data reduction is limited, in this case, to base-band filtering and shifting. The radio link needs to face a massive flow of data, from 2 to 6 Mbps, with bit error rate requirements ranging from 10^{-3} to 10^{-5}. At the same time, long ranges are necessary for significant multistatic sonar tests (10 n.mi).

DUSS radio link experiments

A conventional radio link has been implemented and successfully tested at sea. Antenna mast height above the water, transmit power, receive antenna gain represent the most critical issues. Two different working frequencies have been tested, 0.4 and 2.3 GHz, with equivalent overall performance, but different features. Figs. 9 and 10 show the reconstruction of propagation conditions after model validation with experimental data. The objective of 10 n.mi. ranges at 2 Mbps was accomplished by both frequencies with powers of 6 W and antenna gains of 22 dB (2 GHz) or 20 W with antenna gains of 7 dB (400 MHz).

As discussed above, spread-spectrum techniques and other signal modulation and coding schemes deserve serious attention. Their interaction with the peculiar environment of the present application (air-sea boundary) may result in remarkable improvements of system performance and reliability. The most relevant limiting factor derives from multipath and destructive interference from the sea surface reflected signal. Spread spectrum is expected to counter such effects, providing at the same time a better rejection of man made interference.

Computer simulations have been conducted with AREPS to determine the practical transmission range for DUSS with spread spectrum techniques, in three representative cases. Case A accounts for an elevated communications relay station (33 m above sea level), that could either be the mast of a support ship (e.g. NRV *Alliance*), a moored buoy with a communications payload connected to a tethered balloon, or an antenna installed ashore, in case of littoral surveillance (e.g. a harbor). Cases B and C are representative of LOS buoy-to-buoy communications, with antennae 6 m and 9 m above sea level, respectively.

	Transmit power	**Range (n.mi)**
Case A (33 m)	0.1 W	6.1
Case A (33 m)	1 W	10
Case B (6 m)	0.1 W	3
Case B (6 m)	1 W	4.7
Case B (6 m)	6 W	6.8
Case C (9 m)	0.1 W	4
Case C (9 m)	1 W	6.6
Case C (9 m)	6 W	9

Validation of this estimation has been produced during engineering tests conducted with the following link:

Lucent WaveLAN IEEE Turbo at 0.5 Mbps. 2.4 GHz, 100 MHz passband, 1 Watt RF power.

- 9 dBi omni antenna at 33 m on Alliance, 11 dBi omni co-linear antenna at 30 m on Formica Grande island. Link up to 12 km range, with periodical signal loss.
- 9 dBi omni antenna at 33 m on Alliance, 15 / 24 dBi directive Yagi / parabolic antenna at 20 m on Formica Grande island. Link up to 25 km range, with periodical signal loss.
- 9 dBi omni antenna at 33 m on Alliance, 7 dBi omni co-linear antenna at 7 m on buoy. Link up to 6 km range, with periodical signal loss.

The result is that, adopting spread-spectrum transmission, it is possible to communicate at a range compatible with DUSS operations, using a limited transmit power (1 W). This result is extremely important when operating from a battery-powered platform, where a trade-off exists between transmit power and battery duration. The execution of practical tests at sea is warmly recommended, due to the variability and uncertainty introduced by the environment, and is made easier by the reduced costs and efforts involved.

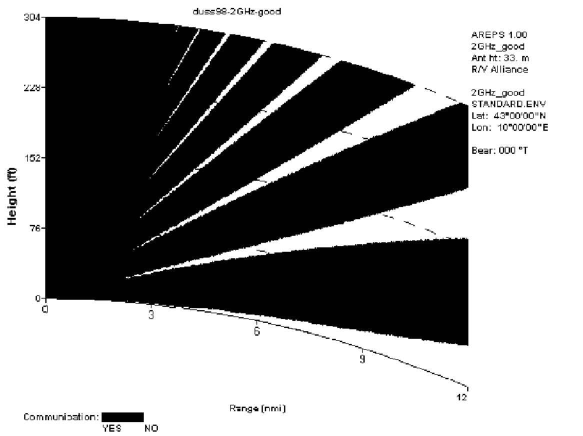

Figure 7 - AREPS output for 2.28 GHz link.

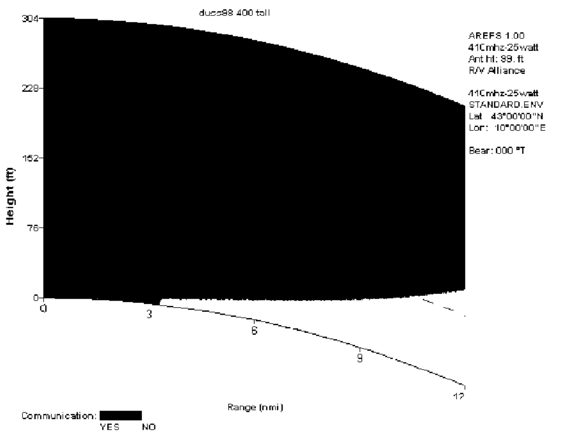

Figure 8 - AREPS output for 400 MHz link.

The concept of a "repeater" buoy is also promising, in the attempt to align radio ranges to acoustic performance. The following figure 9 illustrates a tactical network of DUSS nodes configured according to Case A, described above. A repeater buoy is used to reach buoys positioned beyond line of sight (LOS).

The availability of cost-effective off-the-shelf systems also represents a very attractive issue for scientific applications. Such systems can be very easily interfaced to a computer-controlled buoy, thus providing additional advantages in terms of remote operation of the system. Finally, no special licenses are required for the access to existing channels, thus making easier the organisation of tests at sea.

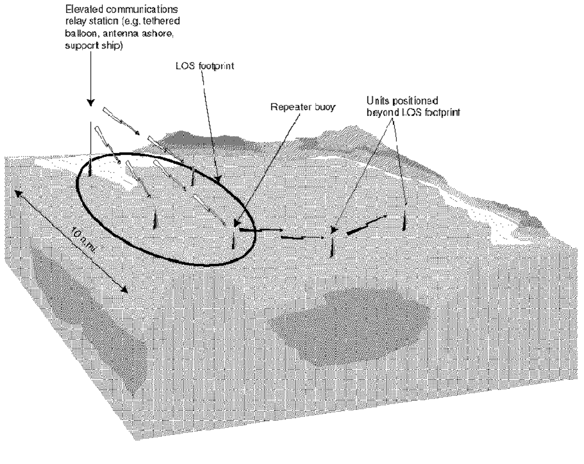

Figure 9 - Example of DUSS WLAN deployment pattern, using an elevated communications relay to extend LOS range and a repeater node to reach nodes beyond LOS (drawing not to scale)

DUSS and radio links for operational concept demonstration

This case presumes the capability to reduce the flow of data transmitted across the transmission channels by an in-buoy processor. At the same time, the physical radio link is required to set up a multi-point wireless LAN. Each buoy operates in a partial-knowledge/partial-connection configuration, exchanging the minimum necessary information with neighbouring buoys in order to identify and track contacts in their progress through the sonobuoy field.

The bi-directional exchange of contact information between neighboring buoys becomes therefore vital for the existence of DUSS as a system. This traffic overlaps to the flow of information packets towards the surveillance command site. DUSS becomes a true wireless network of independent, interacting sonar surveillance units.

Work on smart data reduction is going on, towards the definition of a minimum information size and structure for the identification and integration of contacts without performance loss. The performance and methodologies of data exchange therefore become a key factor for the determination of sonar surveillance performance.

All the typical features of packet switching networks can be inherited by DUSS, as redundancy, fault tolerance, and diversity of communication paths through the network towards the final destination(s) of surveillance information. Techniques, protocols and commercial systems developed for the civilian communication market can be profitably applied to the present application. The limited traffic generated by each unit makes it possible to consider both satellite and classical radio links. Spread-spectrum radios provide the necessary sharing of bandwidth, as well as covert, robust transmission. Techniques and experience derived from the Internet and cellular phone applications are expected to provide valuable contributions both in terms of concept development and of implementation of a demonstrator.

Another concept that is being studied is the adoption of wireless ship-to-ship local area networks in support of Low Frequency Active Sonar (LFAS) in multistatic configurations. The WLAN will enable the near real-time exchange of contact information between the participating platforms, to achieve better accuracy through sonar display correlation. At sea experiments are scheduled for November 2000 as a preparation of the Cerberus experiment, to take place in the second half of 2001.

Is SATCOM a suitable alternative to a spread-spectrum tactical network?

One last word is spent to discuss the role of SATCOM in the fulfilment of the communication requirements discussed so far. In particular, it is interesting to assess whether Low Earth Orbit (LEO) SATCOM systems can efficiently substitute ad-hoc wireless networks deployed on the field. The constraints associated to SATCOM are the narrow bandwidth that is presently made available for data communications and the high associated cost. As an example, providing 24 hours a day connectivity to 10 platforms (e.g. buoys, ships) using the Globalstar system would cost between $12000 and $18000. Those costs could be reduced activating the link on demand, instead of keeping it open 24 hours a day.

Supported data rates are also very limited, in the order of 2.4 kbps. This is acceptable for less demanding applications, such as transmission of positioning information, but is hardly adequate for REA or DUSS operations, unless radical data compression/data reduction schemes are adopted.

Until more performing and cost-effective alternatives are presented, the most practical solution is to deploy tactical wireless networks granting full coverage of the geographical area of interest, using SATCOM gateways to ensure interconnection with land-based infrastructures (e.g. wide area networks).

Conclusions

- Using spread-spectrum, transmit bandwidth can be traded for transmit power (good for battery operation)
- Resistance to multipath, derives from the narrow auto-correlation of the spreading function of Direct Sequence techniques or from the short time slice duration of Frequency Hopping techniques.
- Other features that are not offered by classical systems are low probability of detection and low probability of intercept.

- Spread-spectrum systems play a vital role in all modern telecommunication systems (both military and commercial). They also play a central role in current US DoD research projects on wireless networking in support of the *network-centric warfare* concept, in which operational advantage is achieved from the efficient networking of a geographically dispersed force. This means a focus shift from single autonomous platforms to an integrated network approach.
- The introduction of spread-spectrum communications in Rapid Environmental Assessment and Deployable Underwater Surveillance Systems permits the deployment of distributed and scalable wireless tactical networks of ships and sensors, characterized by reliable performance (survivability, resistance to hostile jamming and environmental interference) and low probability of interception. The high data rates that can be delivered by spread-spectrum systems (up to 10 Mbps) are sufficient to accommodate the most demanding applications that are presently supported.
- The specific requirements of wireless ad-hoc networks include issues such as frequency re-use and multiple access to the same channel, dynamic reconfiguration of network topology, complex variable network structure (including support for moving platforms, such as ships), scalability and quality of service, communications and information security. Further studies will concentrate on this vast and complex subject. Particular emphasis will be put on the issues or resource reservation, quality of service, authentication, and encryption.
- An alternative to spread-spectrum techniques is represented by traditional narrow-band modulation schemes, enhanced by multi-carrier modulation and adaptive equalization techniques. However, implementation of such systems is still at the prototyping phase: additional studies and tests are required before systems become available to end-users.

References

[MBG-99] Mozzone L., Berni A., Guerrini P., Long range, large throughput radio data link for DUSS (Deployable Underwater Surveillance Systems). SACLANTCEN SM-360. La Spezia, Italy, NATO SACLANT Undersea Research Centre, 1999.

[Patt-98] Patterson, W.L., Advanced Refractive Effects Prediction system (AREPS). Version 1.0 User's Manual. TD-3028, Space and Naval Warfare systems Center, San Diego, CA, 1998.

[Sell-99] Sellschopp, J. "Rapid Environmental Assessment", Naval Forces 3/1999.

[Skla-88] Sklar, B., Digital Communications, Fundamentals and Applications, Prentice Hall, 1988 [ISBN 0-13-211939-0]

[TFB-99] Trangeled A., Franchi P., Berni A., Data Communication and Data Fusion Architectures for Rapid Response 96-98, SACLANTCEN SR-296. La Spezia, Italy, NATO SACLANT Undersea Research Centre, 1999.

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